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U.S. ARMY ORDNANCE

Technical Memorandum 1-62

HELICOPTER ARMAMENT PROGRAM

AIR-TO-GROUND TARGET DETECTION AND IDENTIFICATION

Calvin G. Moler

January 1962

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HUMAN ENGINEERING LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

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Calvin G. Moler

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Gerald Goldstone
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APPROVED: [signature]
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U. S. ARMY ORDNANCE HUMAN ENGINEERING LABORATORIES
Aberdeen Proving Ground, Maryland

ABSTRACT

This study was conducted to gather baseline data on the ability of observers to detect, identify, and estimate slant range to typical stationary ground targets from low-flying helicopters.

All subjects were rated pilots with training and/or experience in aerial observation. Targets consisted of five types varying in size from the M-48 tank to a single machine gun on antiaircraft mount.

Rank order of target types as determined by frequency of detection was tank, jeep w/recoilless rifle, support platoon, Scorpion, and machine gun. Tables of probabilities of detection, probabilities of correct identification, and the ranges at which each target type was most often detected are presented in this report.

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HELICOPTER ARMAMENT PROGRAM

AIR-TO-GROUND TARGET DETECTION AND IDENTIFICATION

INTRODUCTION

The Army is currently interested in the use of armed helicopters when, due to time or terrain, conventional artillery weapons cannot be brought to bear on enemy targets. Because of its relatively slow speed and absence of personnel and aircraft protection, the helicopter's best tactic for survival is found in its inherent adaptability to "nap-of-the-earth" and "contour" flight. * Since noise generated by the rotor blades, although audible, cannot be readily directionalized by ground troops, such maneuvering capabilities provide two definite advantages; the ability to hide and the element of surprise. The question then arises as to the effectiveness of a helicopter operating in such a flight mode. The Human Engineering Laboratories' helicopter armament program, of which this study is a part, has been designed to gather baseline data from which such information may be computed and consequently evaluated.

PURPOSE

While we have an approximation of a trained observer's ability to detect and identify ground targets from fixed-wing aircraft (1), little information exists on the improvement or degradation attributable to rotary wing aircraft operating at or below tree top level. For this reason, at the request of the Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, the Human Engineering Laboratories set about to establish a baseline for susceptibility of typical stationary ground targets to detection, identification, and range estimation from helicopters executing such flight. In brief, this study was designed to yield the following information:

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* Contour flight is accomplished by flying as close to the ground as possible without altering course, rising only to clear trees, hills, or any objects along the way; literally following the contour of the earth on a given course.

Nap-of-the-earth takes advantage of all natural terrain features by flying down gulleys and river beds, around trees and hills, and reaching a designated point by any route which affords maximum cover.

(1) Field Test of Visual Reconnaissance Capabilities, WADC TR 54-530.

a. The probability of detecting military ground targets.

b. The types of ground targets most likely to be detected.

c. The types of ground targets most likely to be correctly identified.

d. The accuracy with which target range can be estimated under the previously discussed conditions.

e. The influence and extent such factors as angle of approach and light and shadow have on detection and slant range estimation.

METHOD

Subjects

Thirty-two pilots stationed at Fort Ord, Monterey, California, were chosen to act as observers. All were rotary and/or fixed-wing rated with aerial observation training and/or experience. The average age was 29-1/2 years with an average flight time of 1,486 hours. Since the subject was his own control for each of the independent variables, no test for matching of subjects was required.

Test Site

Since there is in reality no such thing as "typical terrain", an area encompassing three general types (rugged, rolling, and flat - all with varying degrees of cover) was chosen for conduct of the study. The CDEC (Combat Development Evaluation Center), Hunter-Liggett Military Reservation, was selected as the best available site most closely fulfilling these requirements.

Equipment

1. Four H-13 helicopters

2. Nine M-48 tanks

3. Nine 106mm jeep-mounted recoilless rifles

4. Nine 50 cal. machine guns on antiaircraft mounts, each with a two-man crew

5. Nine Scorpions (90mm self-propelled gun)

6. Nine support platoons, each consisting of three 81mm mortars with a three-man crew

7. Tape recorder capable of recording as high as four channels simultaneously

8. Communications system

9. H-21 helicopter photo-ship

10. L-19

11. Four 70-milimeter hand-held cameras

12. Controlled photo mosaic of the test area

PROCEDURE

The test region consisted of an 8 kilometer by 8 kilometer square, subdivided into nine equal squares into which one of each of five types of targets were randomly placed. Five appropriate target types were selected, representing five different degrees of fire power and target area size; each with a comparable counterpart in a potential agressor's arsenal of weapons (Fig. 1). Chosen as representative targets were (1) the M-48 tank, (2) a 106mm jeep-mounted recoilless rifle, (3) a .50 cal. machine gun on antiaircraft mount with crew, (4) the Scorpion, a self-propelled 90mm gun, and (5) a support platoon consisting of three 81mm mortars, each with a three-man crew.

After being randomly placed, by using a contour map and with the aid of personnel from the Tactics Division, U. S. Army Ordnance School, Aberdeen Proving Ground, each target was moved to the nearest strategic defensive location for that particular target type and listed with its respective map coordinates. Once located in the field, each position was moved to the nearest available natural cover within a 50-meter radius, staked, and marked with two 9-foot panels forming a "T" clearly visible from the air.

Radar, the first considered and seemingly easiest method for tracking the helicopter, was eliminated because of heavy ground return and contact loss due to terrain. For this reason, photography was adopted as the chief means for data collection and, upon completion of the region layout, a series of photographs covering the entire area was taken from an altitude of 6,000 feet.

M-48 Tank

Scorpion

Jeep-Mounted 106mm Recoilless Rifle

Support Platoon

Machine Gun on Antiaircraft Mount

Fig. 1. Five Target Types Used in Study

5. Nine Scorpions (90mm self-propelled gun)

6. Nine support platoons, each consisting of three 81mm mortars with a three-man crew

7. Tape recorder capable of recording as high as four channels simultaneously

8. Communications system

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These in turn were used to assemble a 9-by-9-foot controlled mosaic of the region with each target position clearly marked for easy identification (Fig. 2). The panels were then removed and replaced with the proper targets in readiness for the study. The mosaic, prepared by the 30th Engineer Battalion of Ft. Belvoir, Virginia, represents a composite of over 500 photographs.

To afford each subject an equal opportunity to search the area, an "S" type flight pattern was adopted (Fig. 4). Of the eight predetermined courses, there were basically only two; north-south and east-west. The remaining six differed only in entrance points to the test region and, consequently, direction of flight. Eight courses were chosen for the purpose of avoiding any biasing effects of sequence of targets on the results, minimizing any possible learning cues, and balancing light and shadow as well as angle of approach to the target. Four pilots were trained to fly the courses (two in each of the two basic directions), maintaining a ground speed of 60 mph so that allotted time for each run remained constant.

Throughout each experimental flight the H-21 photo-ship flew directly above the H-13 project helicopter, following its flight path as closely as possible and photographing on cue from the subject observer. In order to assure no deviations from the flight path would go unnoticed should they occur, an L-19 flew above both ships reporting the location and time of any such deviations to the Ground Control Center (GCC). The project helicopter, photo-ship, Ground Control Center, and Air Control Center were all in the same communications net and linked to a tape recorder located at the GCC (Fig. 3). So as not to interfere with any transmissions from the project helicopter, the L-19 reports were fed to the GCC and tape recorder over another frequency.

The subjects were first familiarized with the study and its purpose and shown photographs of the five target types to be detected and identified. They were then instructed in proper use of the radio and acquainted with the simple identification responses associated with each target type. The M-48 was identified by the word "Tank", the 106mm jeep-mounted recoilless rifle by "Jeep", the machine gun by "Ack-Ack", the Scorpion by "Gun", and the Support Platoon simply by "Toon". Subjects were told to give three responses for each target whenever possible and to observe radio silence at all other times. Each subject was required to make at least 2 runs over the region, each time from a different entrance point and in a different direction.

Upon initial sighting of any of the targets, observers were asked to respond by saying "Target". At this point it was not necessary to know the identity of the target, but simply to know that one was being approached. The second and third responses were actually combined, identifying the target by name and slant range estimation in yards and by clock position. A complete localization of any target would then be transmitted in the following sequence: "Target" followed by identification "Tank", and the

Fig. 2. Controlled Mosaic of the HLMR Test Area Used in Scoring of Results

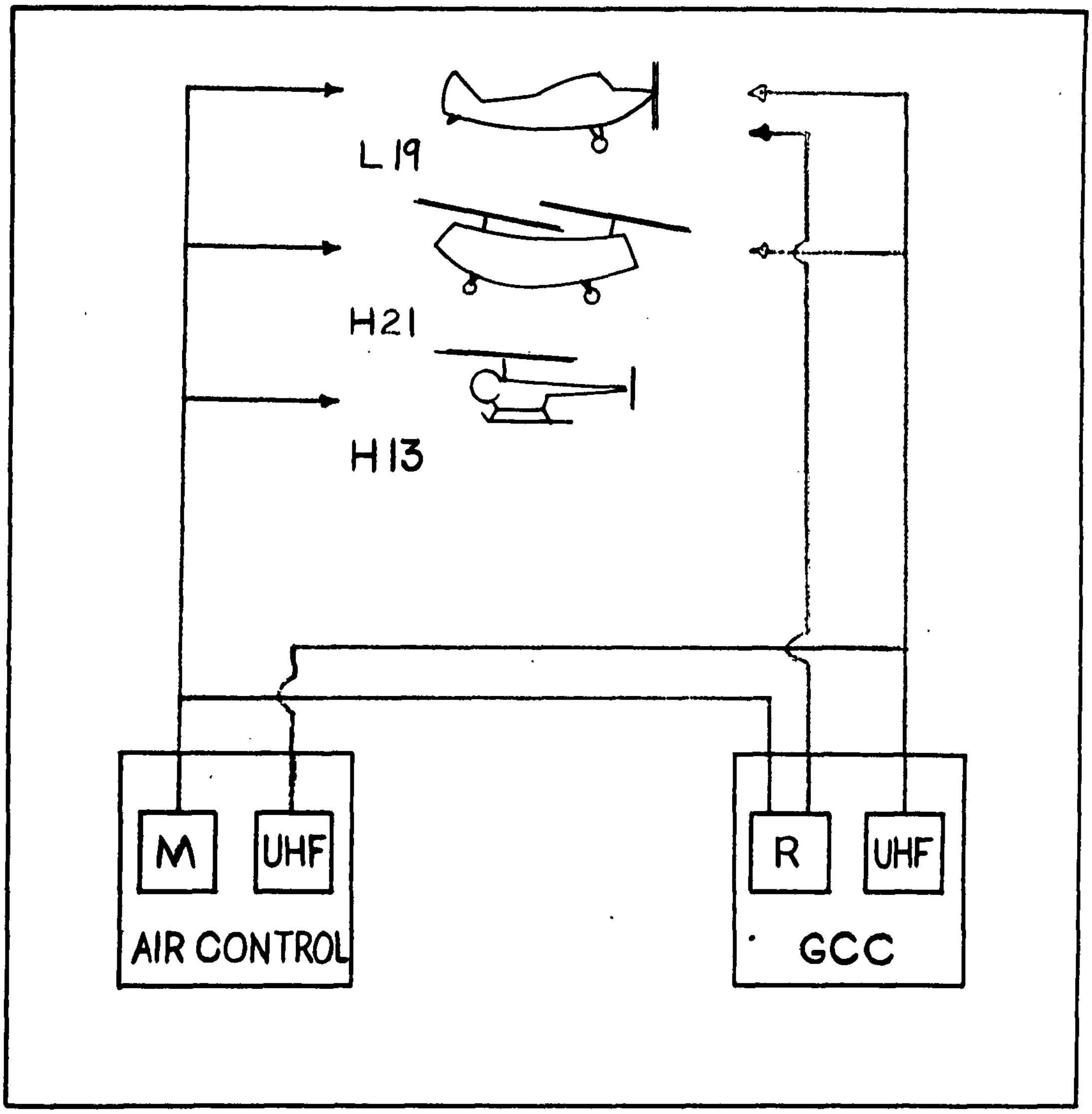


Fig. 3. Communications Net as Set Up and Operated Throughout Study

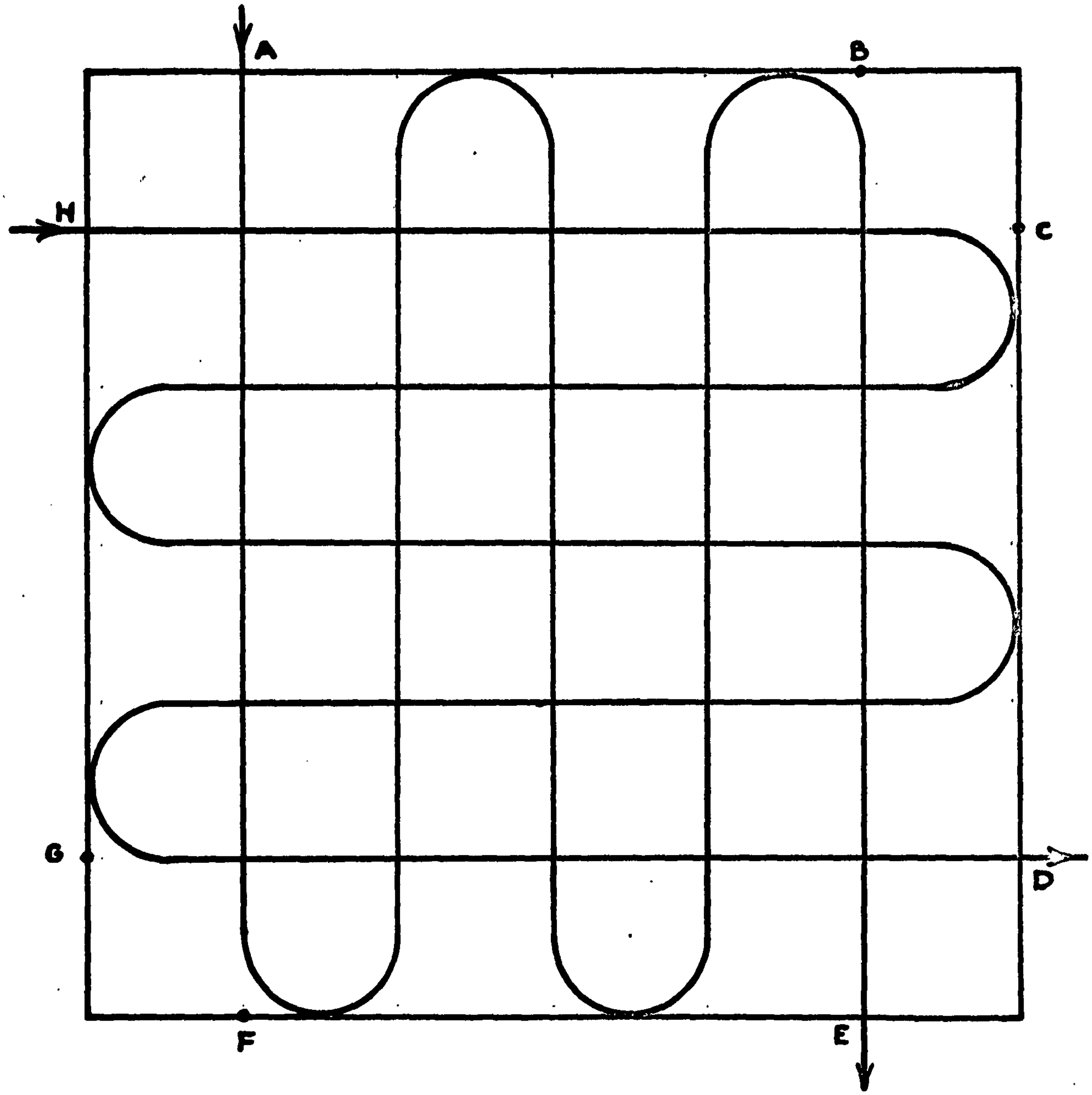


Fig. 4. Two of the Eight Flight Paths Used in the Study - Flight Path A and Flight Path B. The remaining six were achieved by using entrance points B, C, D, E, F, and G and flying the same basic pattern.

"500 yards at 11 o'clock". If a target was detected but not identified, radio silence was maintained until another target was detected. If a target was detected and falsely identified, the observer, upon recognition of his mistake, would identify a second time giving the corrected identity, range, and position. Car and tank wreckage scattered throughout the area prevented observers from identifying all objects foreign to the terrain as targets. In addition, several years of field maneuvers made it impossible to use tracks left by the targets moving into position as tracers.

It was discovered in pre-experimental interviews that, because of the short period of time in which the metric system has been in use in this country, subjects were still thinking in terms of yards though reporting in meters. In an effort to eliminate as much error as possible, all estimates were given and recorded in yards. However, the final results appear on the graphs in both yards and meters.

An experimental flight began by first briefing the helicopter pilot on his entry point into the test region and then relaying such information to the photo-ship. Enroute to the test region, the observer made three typical transmissions preceded by the word "Testing". This served as a check on the communications system and the observer's radio procedure and sequence of target identification. As the helicopter approached its entrance point, the photo-ship would transmit a count-down from 3 to 0 followed by the word "start", designating the beginning of the run. On detection (transmission of the word "Target"), an aerial photograph was taken of the helicopter, recording its position over the terrain. As the response for identification was received, a second photograph was taken, once again positioning the helicopter within the test region. This same procedure was followed throughout the entire run, geographically locating the helicopter at each instance of detection and identification. Since radio silence was observed at all times other than upon target detection and identification, a photograph was taken each time a transmission occurred. As the helicopter left the test region, the photo-ship would again transmit a count-down from 3 to 0, this time followed by the word "stop", signifying completion of the run. At this time, the second project helicopter would take off for the test region and its assigned point of entry.

By comparing those photographs taken during each run with the mosaic, the position of the helicopter in the test region at the time of each detection and identification was pin-pointed. Since the target identifications and locations were indicated on the mosaic, by reading the taped responses and checking the helicopter positions, identifications could be checked for correctness, ranges determined, and errors computed.

TABLE 1

PROBABILITIES AND RANGES OF TARGET TYPES

	Tank	Recoilless Rifle	Support Platoon	Scorpion	Machine Gun
Probability of Detection at or Before the 0 to 50 Yard Minimum Range	.38	.15	.13	.12	.06
Probability of Correct Identification	.35	.12	.12	.06	.05
Maximum Range of Detection	1400 Yds.	950 Yds.	700 Yds.	1350 Yds.	620 Yds.
Range at which Greatest Frequency of Detections Occurred	300 Yds.	50 Yds.	300 Yds.	100 Yds.	100 Yds.

RESULTS

Rank order of target types, as determined by frequency of detection, was (1) tank, (2) jeep-mounted 106mm recoilless rifle, (3) support platoon, (4) Scorpion, and (5) machine gun. The M-48 tank, the most frequently detected, was spotted better than 2.5 times as often as the jeep-mounted recoilless rifle (the next most frequently detected target), and almost 7 times as often as the machine gun. The machine gun, considered to be a point target, was detected only 33 times out of 513 possibilities throughout a total of 57 record runs. Probabilities of detection by target type for this study are shown in Table 1. Aerial photos of targets are shown in figures 5, 6, 7, 8, and 9.

Absolute maximum ranges at which targets were detected varied from 1400 yards for the tank to 620 yards for the machine gun. In all cases the highest number of detections occurred at no greater than 300 yards.

At or before a minimum range of 0 to 50 yards, the probability of detecting the M-48 was found to be 0.38. However, at the maximum range of 1400 yards, detection probability had dropped to a figure of 0.009. As previously stated, the greatest number of detections occurred at 300 yards with only a scattering of detections at ranges beyond 650 yards.

At a maximum range of 950 yards (considerably less than that of the tank), the jeep-mounted recoilless rifle had a probability of only 0.002. By comparison, 0.009 and 0.02 represented, respectively, detection probabilities of the Scorpion and tank at the same 950 yard range. The Scorpion, though having a smaller cumulative probability at the minimum range, extended to 1350 yards with a probability of 0.004 at that point; greater than that of the recoilless rifle at its shorter maximum range.

Although the maximum range of the support platoon was less than any target other than the machine gun, the 0.13 probability of detection at or before the minimum range was essentially the same as that of the Scorpion. At its maximum range of 700 yards, detection probability was found to be 0.002, with the greatest number of detections occurring at 300 yards.

The machine gun, which was in all cases located in the open on the crest or military crest of a hill, had a cumulative probability of only 0.06 at the minimum range. Absolute maximum range had a probability of 0.002, with 21 of the 33 detections occurring at less than 150 yards.

Curves for each target type showing the cumulative probabilities from minimum to maximum ranges can be found in Appendix A. Comparative probabilities, maximum ranges, and ranges at which greatest frequency of detections occurred are shown in Table 1.

Fig. 5. View of One of the M-48 Tanks as Seen From the Helicopter

Fig. 6. Aerial View of the Jeep-Mounted 106mm Recoilless Rifle

Analysis disclosed, in most cases, a rather high percentage of correct identifications for targets detected. The exception was the Scorpion which had a pronounced decrease in identification probability as compared to its detection probability (Table 1). Although detected throughout a large number of ranges, it was often confused with the tank and identified as such 50 percent of the time. In turn, the tank was identified as a Scorpion only 2.5 percent of the time. However, confusion with the Scorpion was responsible for all but 0.5 percent of the total misidentifications of the tank. No trend was evidenced with any of the remaining target types.

Close examination of Table 1 will disclose a very high percentage of both support platoon and machine gun detections to be correct identifications. Existing weather conditions and positioning of the targets would in all probability be largely responsible for such identifications. The support platoon, because of the nature of its mission, was positioned in relatively open terrain with little or no cover. Since, as previously mentioned, high ambient light conditions existed throughout the study, a pronounced light to shadow contrast was evident in the test area. Under such conditions, the emplacements rather than the weapons became the identifying features, appearing from the air as three dark circular areas arranged in a triangular pattern (Fig. 8). Such a pattern was not only readily distinguishable but directly associated with the mortar emplacement. In like manner, the machine gun, which was in all cases located in the open on either the crest or military crest of a hill, was entrenched and presented the same contrast ratio (Fig. 9). However, since in this case only a single weapon was used, no pattern other than that of the emplacement itself was visible from air. Although not easily detectable at long ranges, once spotted it could not often be mistaken for any other target. Probabilities of correct identification for each target type are shown in Table 1. Graphs depicting the cumulative probabilities of correct identification found in this study are shown in Appendix B.

Since no two pilots fly exactly alike, regardless of the amount of training prior to conduct of a study, there arose the question of the effect of individual project helicopter pilots on target detection by observers. In order to assure there was no difference in the number of targets detected as a function of the helicopter pilot, a simple analysis of variance was computed and no significant difference found. The results are shown in Table 2.

Fig. 7. Aerial View of the Scorpion

Fig. 8. Aerial View of Support Platoon Showing Light-to-Shadow Contrast

Fig. 9. Aerial View of Machine Gun Showing Effect of Shadow on Identification

TABLE 2

PILOT DIFFERENCE

Summary of Analysis of Variance for Observer Scores by Pilots

SOURCE	df	SS	MS	F
Treatments	3	16.02	5.34	
Within Groups	72	634.97	8.82	0.61
Total	75	650.99		

Weather was clear and sunny throughout the entire study producing a high light to shadow contrast. Record runs began at 0700 hours and continued until 1700 hours, a period seemingly long enough to give some idea of the effects of light and shadow on target detection. However, because of the geographic location and the time of year during which the study was conducted, shadows cast by hills and vegetation were not too lengthy. Light limitations imposed by the photographic scoring technique prevented investigation beyond these hours. As a result, the effects of larger shadows and less contrast could not be determined. Under the conditions of this study, no significant difference in the number of detections reported existed as a result of time of day. A simple randomized analysis of variance for the ten daily flight periods was computed with a result of no significant difference between flight times (Table 3).

TABLE 3

FLIGHT PERIOD DIFFERENCES

Summary of Analysis of Variance Comparing Flight Periods

Between 0700 and 1659 Hours

SOURCE	df	SS	MS	F
Treatments	9	76.59	8.51	
Within Groups	66	574.40	8.70	0.98
Total	75	650.99		

Results of the hours before 1000 and after 1400 were then combined and compared against those of the flights run between 1000 and 1400 hours. Once again there was no significant difference. The results are shown in Table 4.

TABLE 4

COMBINED FLIGHT PERIOD DIFFERENCES

Summary of Analysis of Variance Comparing Flight Periods
Between 0700-1000 and 1400-1659 Against Mid-day Flight
(Period 1000-1400)

SOURCE	df	SS	MS	F
Treatments	1	10.25	8.51	
Within Groups	74	640.74	8.70	0.98
Total	75	650.99		

Data was analyzed to determine whether there was a tendency to either overestimate or underestimate range. No such tendency was evidenced. Analysis disclosed 46 percent of the calls to be overestimated and 54 percent underestimated.

As indicated in the objectives of this study, it had been planned to extract information from the data on the accuracy with which slant range to ground targets could be estimated. Prime interest lies not in error alone, but in error as a function of range. Since the observer was his own determinant on range at the time of target detection, true range at the time estimates were called varied from less than 50 yards to a maximum of 1400 yards. So few estimates fell into any one range interval that information obtained was considered to be unreliable. For this reason it was decided to eliminate such findings from this report and conduct a separate study at a later date.

Although originally it had been planned to determine the time interval between target detection and identification, either because of a desire on the part of the observers to eliminate false detections or because of their inability to see targets at ranges greater than those at which identification was possible, such was not the case and all detections were followed immediately by target identification.

SUMMARY

An investigation of the susceptability of typical stationary ground targets to detection, identification, and slant range estimation from helicopters flying contour was conducted at the Hunter-Liggett Military Reservation in California. Thirty-two rated pilots acting as observers were flown over an area containing nine of each of five target types. Targets were randomly distributed throughout the area and defensively emplaced. Subjects did not know the location of any of the targets and were required to continually search while being flown through the area on a predetermined course.

Results and conclusions were as follows:

a. The maximum range at which any target was detected was 1400 yards.

b. The largest number of detections for each target occurred at a range no greater than 300 yards.

c. Of the five target types used, the tank (M-48) was most often detected. Detection probability for this study was found to be 0.38.

d. Between the hours of 0700 and 1700, the change of sun angle and shadow length had no effect on the probability of target detection.

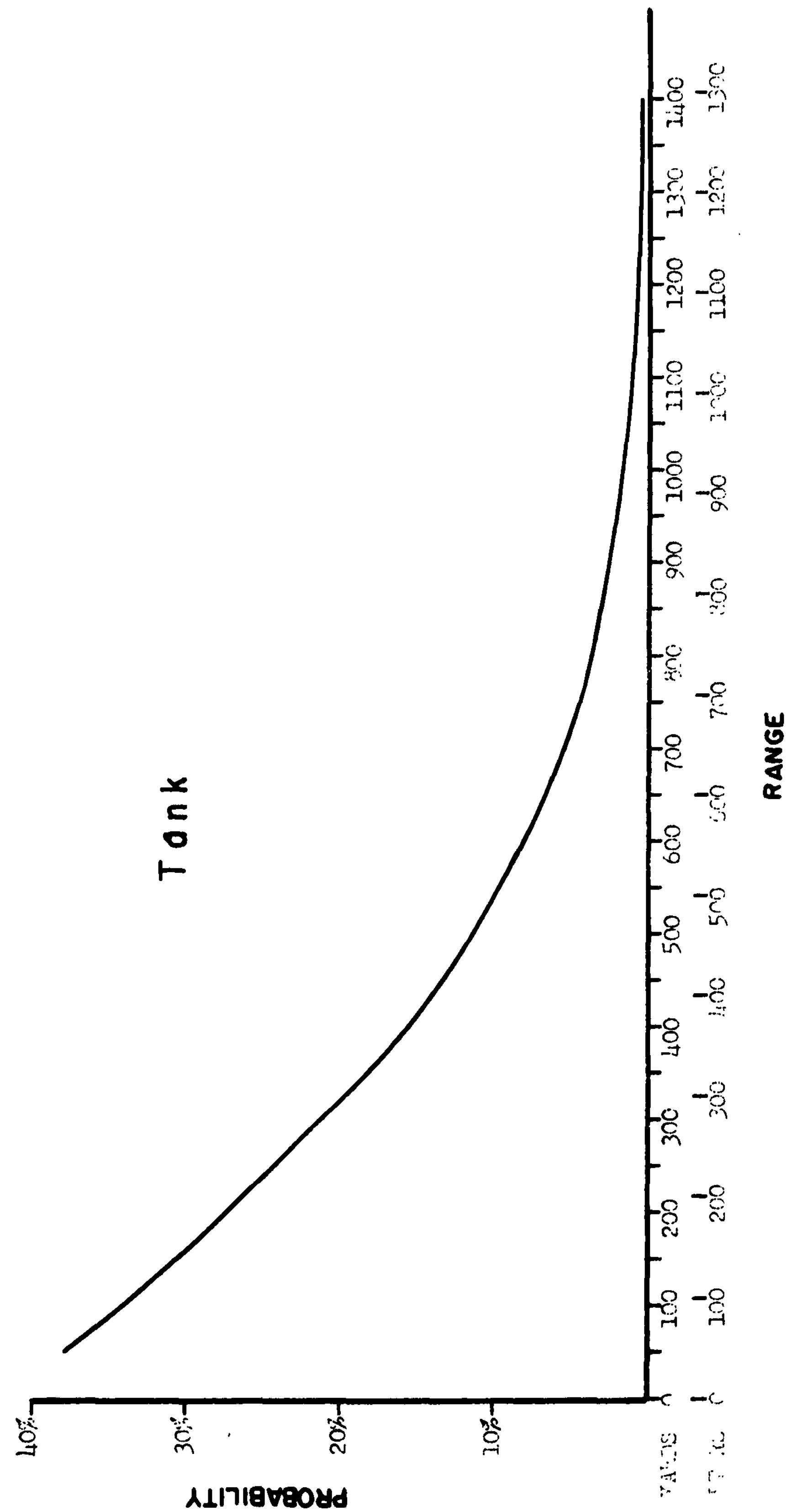
e. Correct identification of targets was relatively high. (See RESULTS section for exception.)

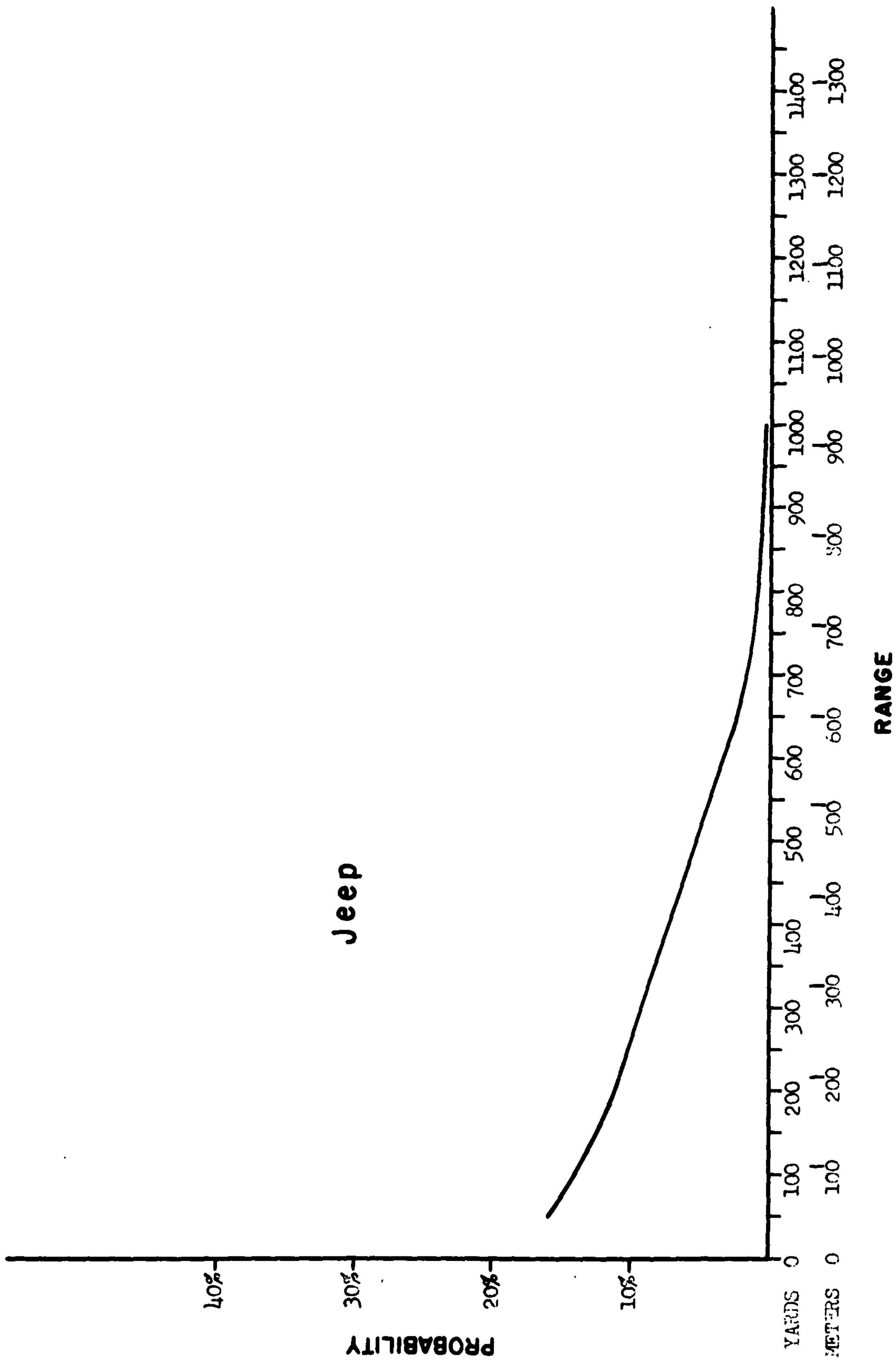
f. Under high ambient light conditions the emplacements of certain weapons, rather than the weapons themselves, became the detecting and identifying features.

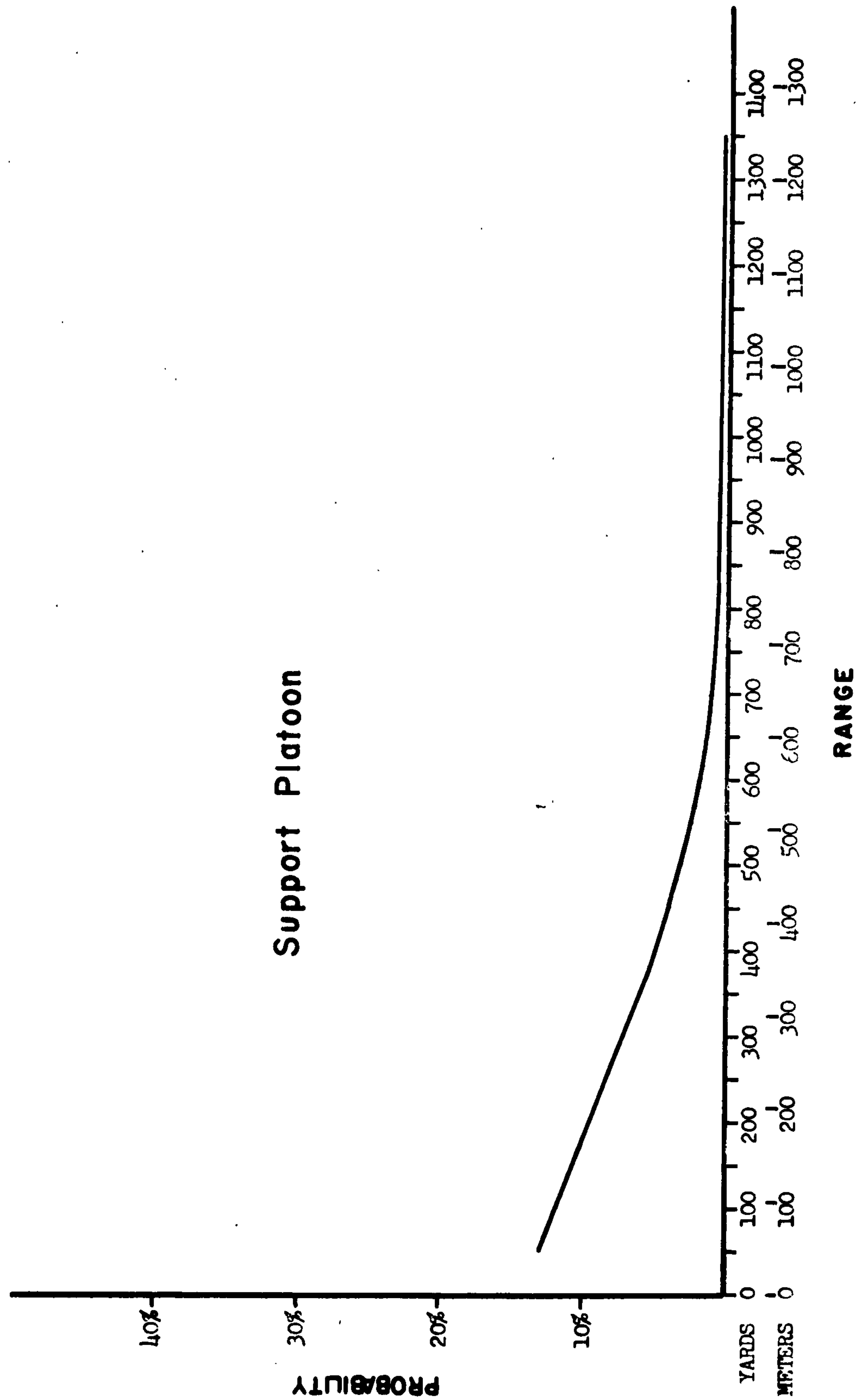
The results discussed herein are meant to serve as a guide for future studies and should not be construed as typical for all low-flying helicopters. General terrain, target concealment, aircraft altitude and speed must be considered in any application of data. Areas of investigation in this study should be examined under more rigid controls both singly and in proper combinations before any final conclusions are drawn.

APPENDIX A

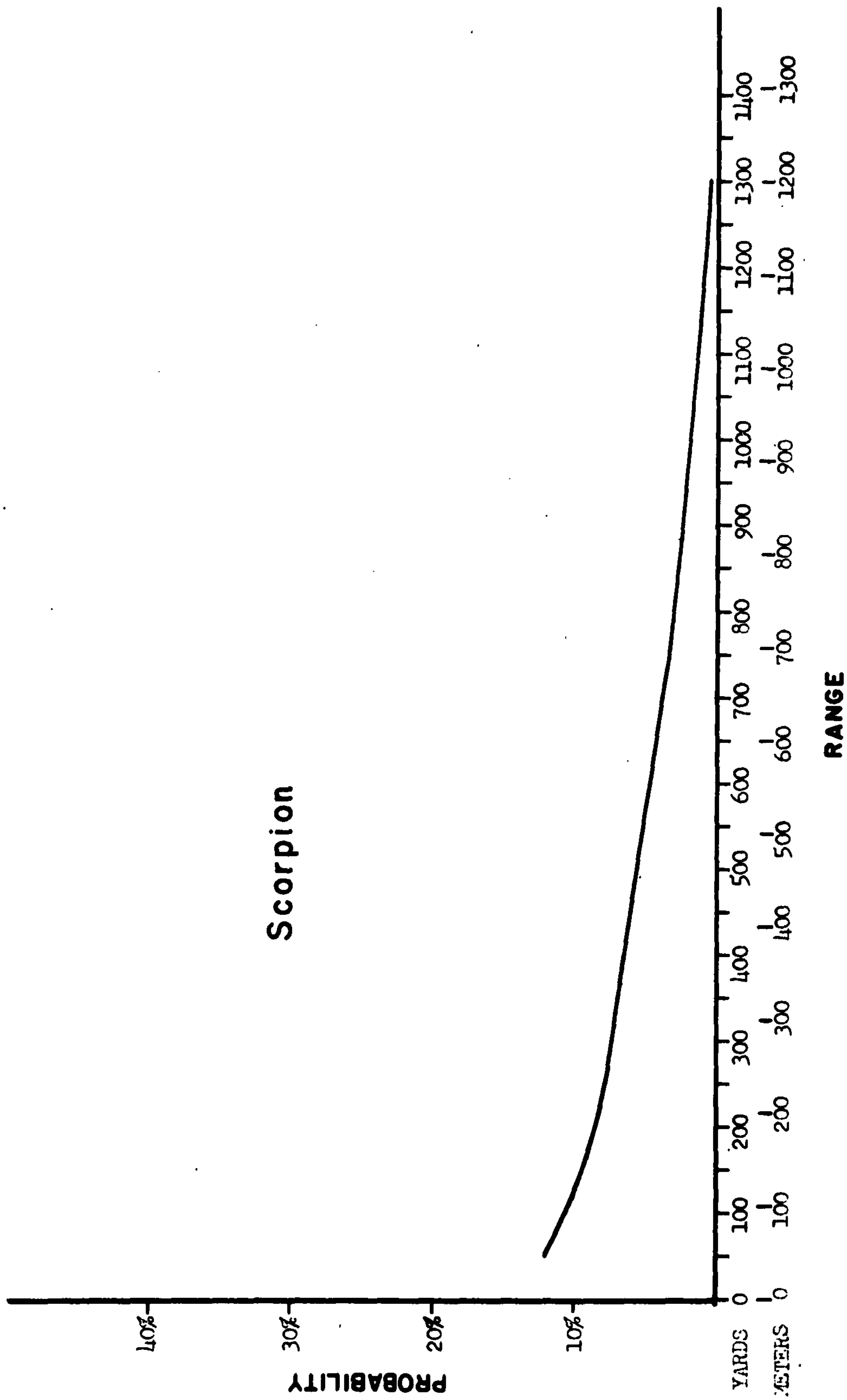
PROBABILITIES OF TARGET DETECTION

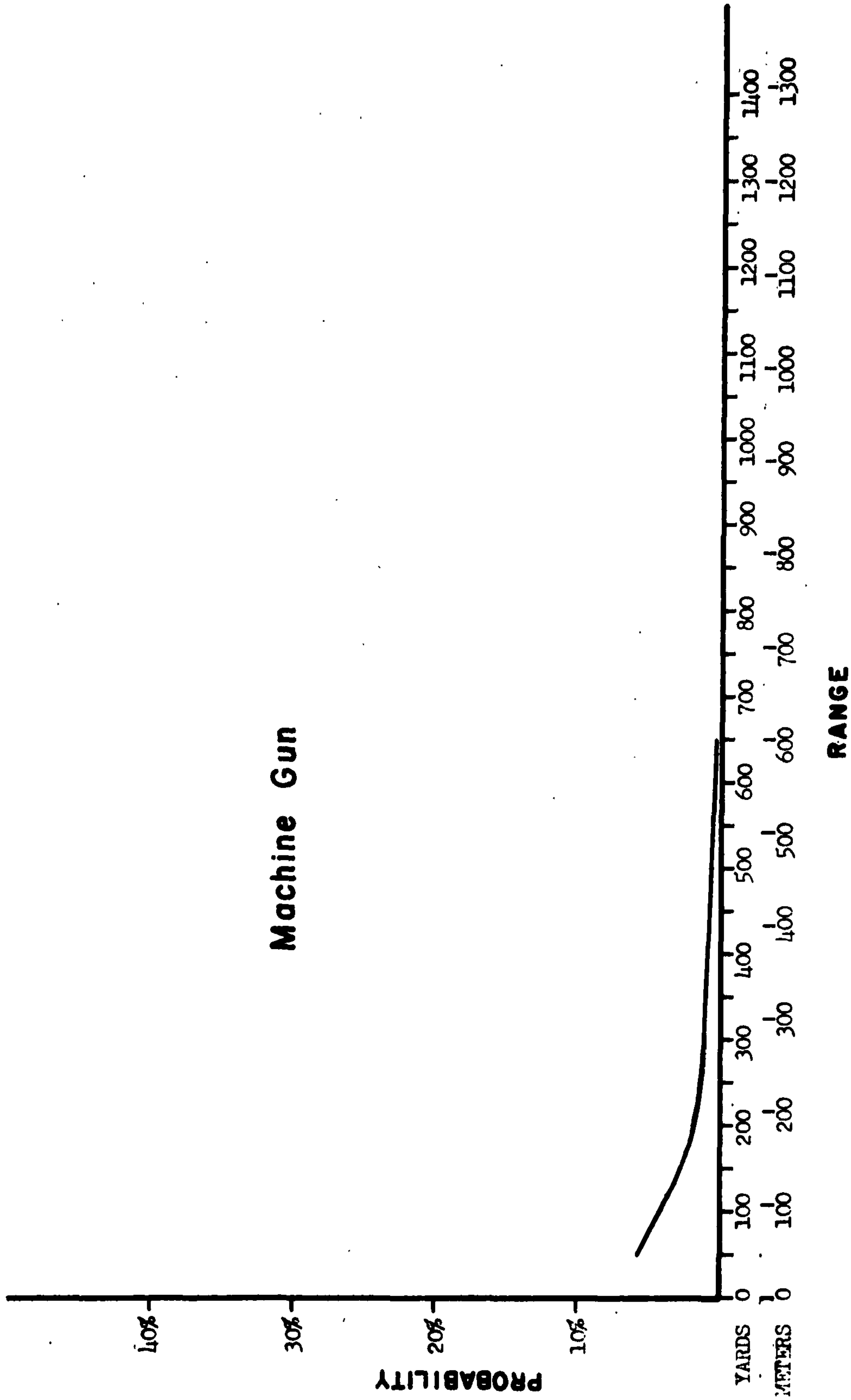

Tank
PROBABILITY
40%
30%
20%
10%
RANGE
0
100
200
300
400
500
600
700
900
1000
1100
1200
1300
1400


Jeep
PROBABILITY
40%
30%
20%
10%
RANGE
YARDS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
METERS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300



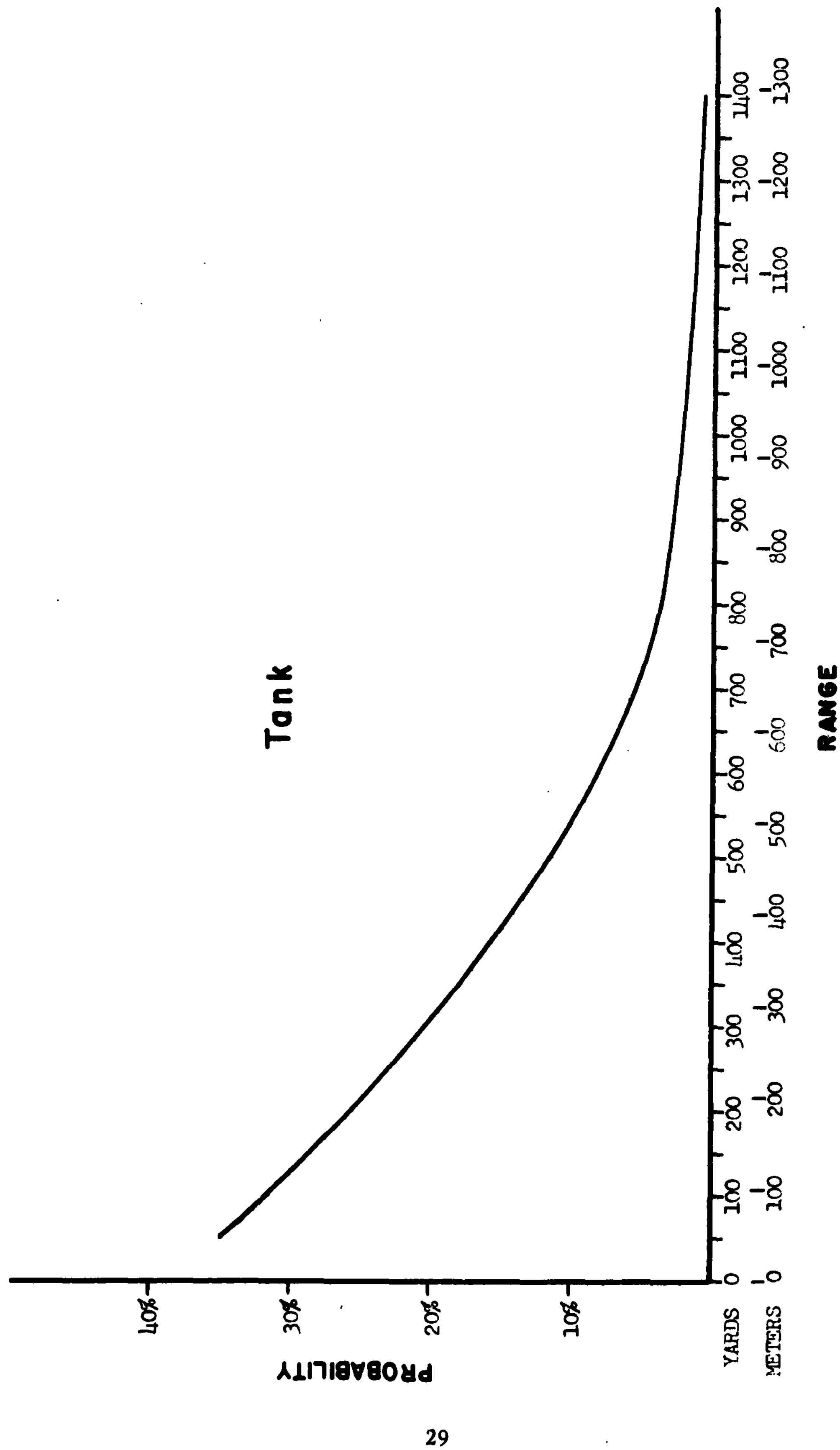
Support Platoon
PROBABILITY
40%
30%
20%
10%
YARDS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
METERS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
RANGE

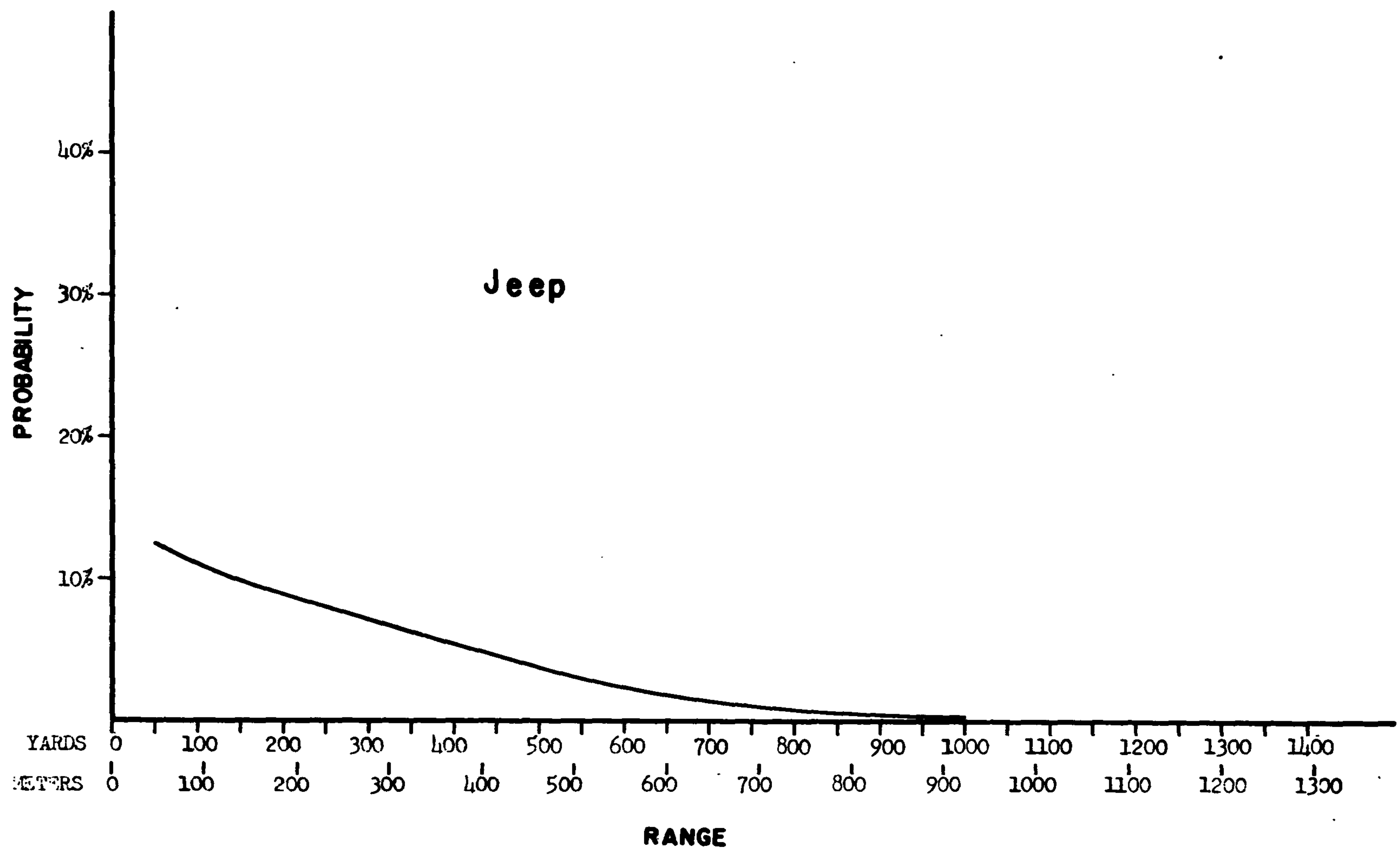

Scorpion
PROBABILITY
10%
20%
30%
40%
RANGE
YARDS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
METERS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300

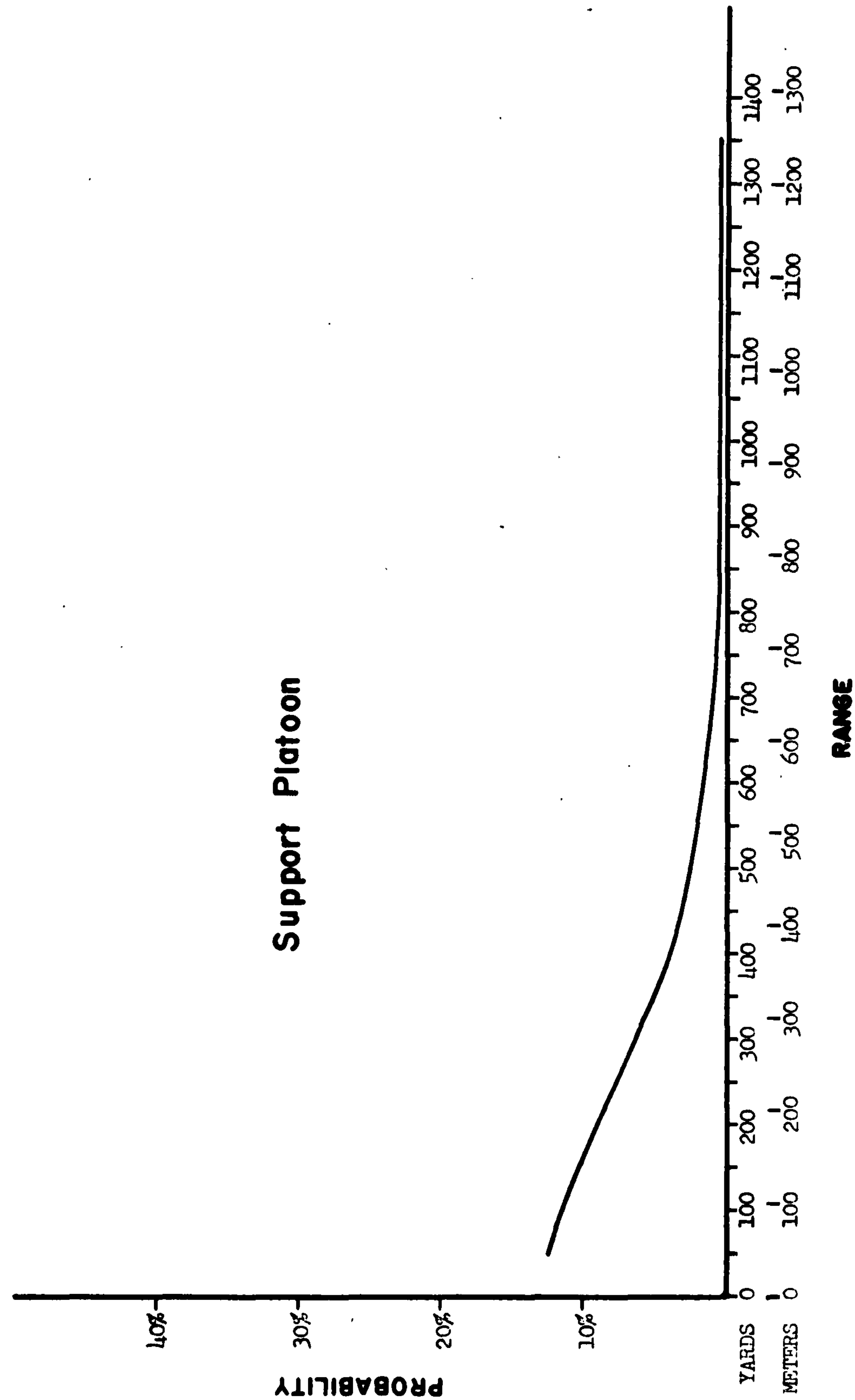

Machine Gun
PROBABILITY
10%
20%
30%
40%
RANGE
YARDS
METERS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400

APPENDIX B

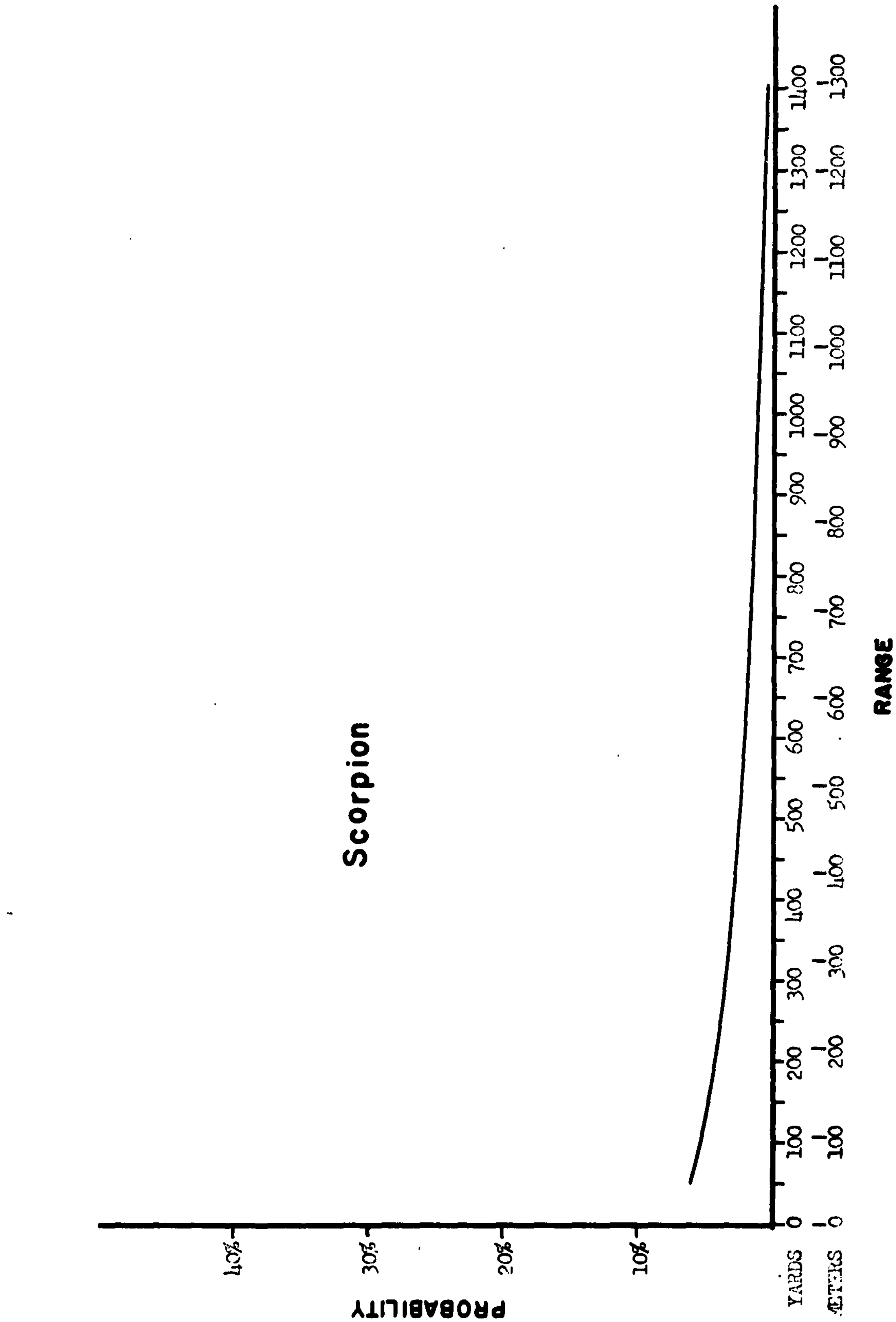
PROBABILITIES OF CORRECT TARGET IDENTIFICATION


Tank
PROBABILITY
40%
30%
20%
10%
YARDS 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400
METERS 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300
RANGE


Jeep
PROBABILITY
40%
30%
20%
10%
YARDS 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400
METERS 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300
RANGE



Support Platoon
PROBABILITY
40%
30%
20%
10%
YARDS
METERS
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300
RANGE


Scorpion
PROBABILITY
10%
20%
30%
40%
RANGE
YARDS
METERS
0
100
200
300
400
500
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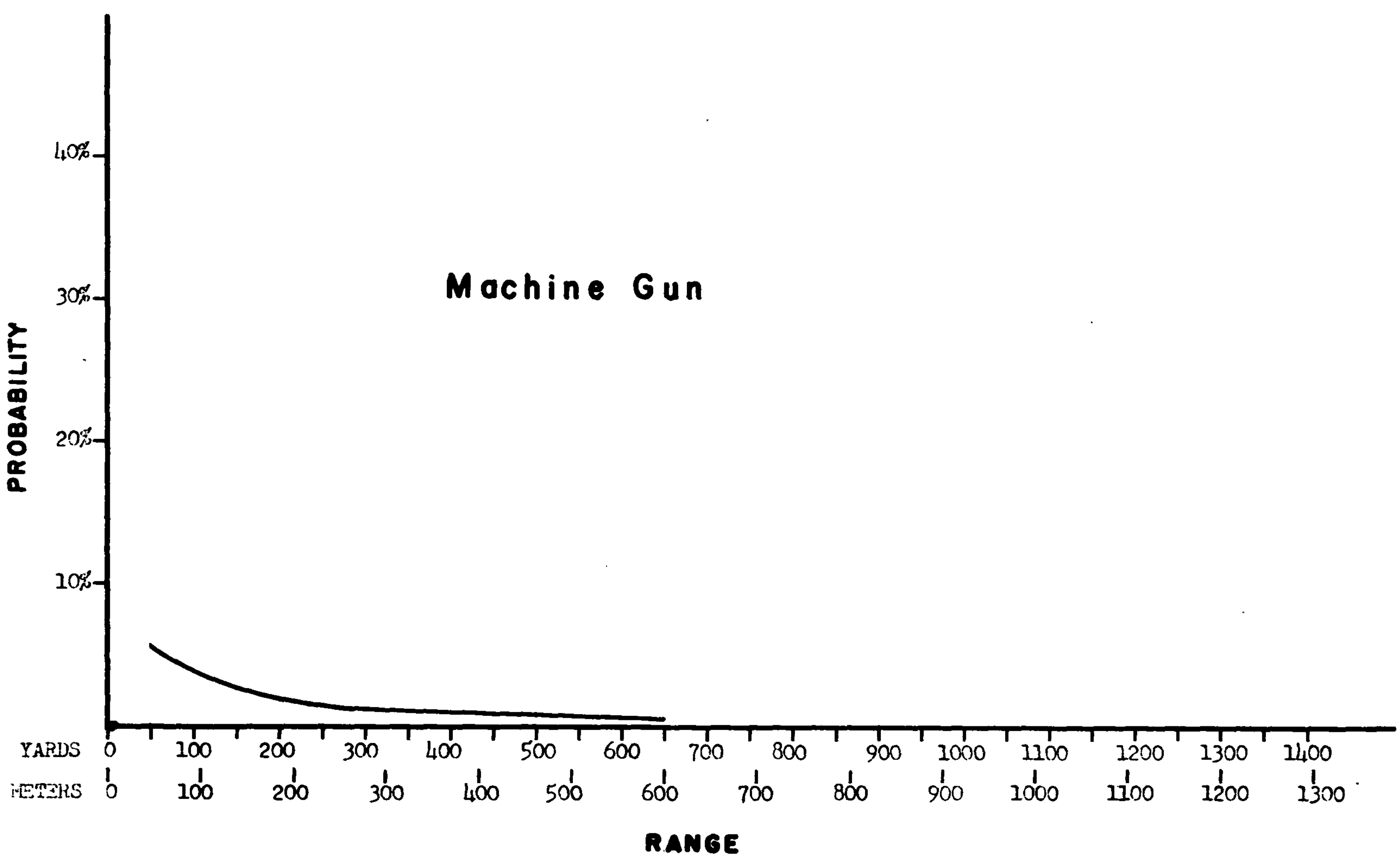
800
900
1000
1100
1200
1300
1400


Machine Gun
PROBABILITY
40%
30%
20%
10%
YARDS 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400
METERS 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300
RANGE

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American Institute for Research
Cascade Bldg., Suite 202A
4020 Buckingham Road
Los Angeles 8, Calif.
Attn: D. J. Nichols 1 cy

American Institute for Research
8 West 41st Avenue
San Mateo
California
Attn: Librarian 1 cy

American Machine & Foundry Co.
11 Bruce Place
Greenwich, Conn.
Attn: Human Factors Supervisor 1 cy

The Franklin Institute
20th St. & Ben Franklin Parkway
Philadelphia 3, Pa.
Attn: Electrical Eng. Library 1 cy

Hughes Aircraft Co.
Florence Ave. at Teal St.
Culver City, Calif.
Attn: Engineering Library 1 cy

ITT Laboratories
500 Washington Ave.
Nutley 10, New Jersey
Attn: Human Factors Group 1 cy

The Research Analysis Corporation
6935 Arlington Road
Bethesda 14, Md.
Attn: Library 1 cy

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AD ____________ Accession No. ____________
USA Ord Human Engineering Laboratories
Aberdeen Proving Ground, Maryland
HELICOPTER ARMAMENT PROGRAM
AIR-TO-GROUND TARGET DETECTION & IDENTIFICATION
Calvin G. Moler, Professional Assistance - Gerald Goldstone and Lynn Oatman
Tech Memo 1-62 OMS Code 5010.21.83202 Unclassified

This study was conducted to gather baseline data on the ability of observers to detect, identify, and estimate slant range to typical stationary ground targets from low-flying helicopters.

All subjects were rated pilots with training and/or experience in aerial observation. Targets consisted of five types varying in size from the M-48 tank to a single machine gun on antiaircraft mount.

Rank order of target types as determined by frequency of detection was tank, jeep w/recoilless fifle, support platoon, Scorpion, and machine gun. Tables of probabilities of detection, probabilities of correct identification, and the ranges at which each target type was most often detected are presented in this report.

UNCL

1. Helicopter - Target Detection
2. Air-to-Ground Target Detection
3. OMS Code: 5010.21.83202
4. Tech Memo 1-62
5. Tech Memo 2-62

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